

Part 1

A Reproduced Copy

OF

(AD-A149163) PROCEEDINGS OF THE FIFTEENTH
ANNUAL PRECISE TIME AND TIME INTERVAL (PTII)
APPLICATIONS AND PLANNING MEETING (Naval
Research Lab.) 745 p HC A99/MF E03

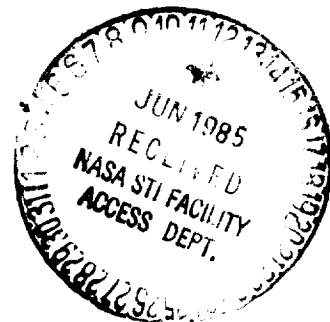
N85-28287
THRU
N85-28324
Unclas
23307

CSCI 14/2 H2/35

Reproduced for NASA

by the

NASA Scientific and Technical Information Facility



AD-A149 163

2

Proceedings of the Fifteenth Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting

A meeting held at the
Naval Research Laboratory
Washington, D.C.
December 6-8, 1983

THIS FILE COPY



PTTI
ELECTRONIC
NOV 5 1984
D

Approved for public release, distribution unlimited.

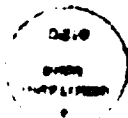
84 10 10 131

Proceedings of the Fifteenth Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting

A meeting held at the
Naval Research Laboratory
Washington, D.C.
December 6-8, 1983

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>

A/1



Sponsored by

Naval Observatory
NASA Goddard Space Flight Center
Naval Electronic Systems Command
Naval Research Laboratory
Defense Communications Agency
Chief of Naval Operations
National Bureau of Standards
Army Electronics Technology
and Devices Laboratory
Rome Air Development Center

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE				
1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS None	
2a. SECURITY CLASSIFICATION AUTHORITY			4. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE				
4. PERFORMING ORGANIZATION REPORT NUMBER(S) None			5. MONITORING ORGANIZATION REPORT NUMBER(S)	
6a. NAME OF PERFORMING ORGANIZATION Naval Research Laboratory		6b. OFFICE SYMBOL (if applicable) 7962	7a. NAME OF MONITORING ORGANIZATION	
6c. ADDRESS (City, State, and ZIP Code) Washington, DC 20375			7b. ADDRESS (City, State, and ZIP Code)	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Naval Research Laboratory*		8b. OFFICE SYMBOL (if applicable) 7962	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c. ADDRESS (City, State, and ZIP Code) Washington, DC 20375			10. SOURCE OF FUNDING NUMBERS	
			PROGRAM ELEMENT NO	PROJECT NO
			TASK NO	WORK UNIT ACCESSION NO 1356-0-4
11. TITLE (Include Security Classification) Proceedings of the Fifteenth Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting				
12. PERSONAL AUTHOR(S) James A. Murray, Editor				
13a. TYPE OF REPORT Proceedings		13b. TIME COVERED FROM 12/6/83 TO 12/8/83	14. DATE OF REPORT (Year, Month, Day) 84 April 2	15. PAGE COUNT 770
16. SUPPLEMENTARY NOTATION (See page ii)				
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB GROUP	Time, Time transfer, Time dissemination, Time measurement, Hydrogen masers, Frequency standards	
19. ABSTRACT (Continue on reverse if necessary and identify by block number) These proceedings contain the papers presented at the Fifteenth Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting, including questions and answers following presentations. The purpose of the meeting was to give PTTI managers, systems engineers, and program planners a transparent view of the state of the art, and opportunity to express needs, a view of important future trends, and a review of relevant past accomplishments; to provide PTTI users with new and useful applications, procedures, and techniques; to allow the PTTI researcher to better assess fruitful directions for research efforts.				
20. DISTRIBUTION AVAILABILITY OF ABSTRACT <input type="checkbox"/> UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
22a. NAME OF RESPONSIBLE INDIVIDUAL J. A. Murray			22b. TELEPHONE (include Area Code) 202-767-2595	22c. OFFICE SYMBOL 7962

DD FORM 1473, 84 MAR

83-101 edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

16. SUPPLEMENTARY NOTATION (Continued)

*Sponsors: U.S. Naval Observatory; NASA Goddard Space Flight Center; Naval Electronic Systems Command; Naval Research Laboratory; Defense Communications Agency; Chief of Naval Operations; National Bureau of Standards; Rome Air Development Center; and Army Electronics Technology and Devices Laboratory

EXECUTIVE COMMITTEE

Schuyler C. Hardrip, Chairman
NASA Goddard Space Flight Center

James A. Buisson
Naval Research Laboratory

Jimmie B. Collie
Naval Electronic Systems Command

Hugh S. Fosque
NASA Headquarters

Dr. William J. Klepczynski
Naval Observatory

Dr. Arthur O. McCoubrey
National Bureau of Standards

James A. Murray, Jr.
Naval Research Laboratory

Dr. Samuel R. Stein
National Bureau of Standards

Dr. Harris A. Stover
Defense Communications Agency

Dr. John R. Vig
Army Electronics Technology and Devices Laboratory

Dr. Gernot M. R. Winkler
Naval Observatory

Dr. Nicholas F. Yannoni
Rome Air Development Center

Sheila C. Faulkner
Naval Observatory
Administrative Assistant

GENERAL CHAIRMAN
Dr. Nicholas F. Yannoni
Rome Air Development Center

TECHNICAL PROGRAM COMMITTEE
CHAIRMAN
Dr. William J. Klepczynski
Naval Observatory

EDITORIAL COMMITTEE CHAIRMAN
L. J. Rieger
Johns Hopkins University/Applied Physics Laboratory

PUBLICITY CHAIRMAN
James A. Duissou
Naval Research Laboratory

SESSION CHAIRMEN

SESSION I

Advances in Time and Frequency Services
Dr. Derek Morris
National Research Council
Canada

SESSION II

GPS Time Transfer
Dr. Victor Reinhardt
Bendix Field Engineering Corporation

SESSION III

Time Transfer/Synchronization
Hugh S. Fosque
NASA Headquarters

SESSION IV

Mathematical and Statistical Techniques and
Their Applications to PTI
Dr. James A. Barnes
Austron Inc.

SESSION V

PTI Components
Dr. Arthur O. McCoubrey
National Bureau of Standards

SESSION VI

Classified Session
Dr. Gernot M. R. Winkler
Naval Observatory

ARRANGEMENTS

James A. Murray, Jr. NRL
Stella Scates, NRL
Susan Ramey, NRL

FINANCE COMMITTEE

James A. Buisson, NRL
S. Clark Wardrip, GSFC

PUBLICATIONS

Elaine Bowers, BFEC
L. J. Rueger, APL
S. Clark Wardrip, GSFC

NRL TECHNICAL ASSISTANCE

James Eng
Stanley Falvey
Alick Frank
Robert Hersh
Chester Kleczek
Mark Lister
Wayne Lloyd
Wade Root
Leighton Williams

PRINTING

Charles V. Hardesty, GSFC
Donald E. Ellis, GSFC

RECEPTIONISTS

Elaine Bowers, BFEC
Sheila Faulkner, USNO
Stella Scates, NRL
Betty Wardrip, GSFC

BANQUET SPEAKER

Robert E. Fischell, APL/JHU

SUBJECT: Time Controlled Release of
Medication By Implantable Devices

FOREWORD

These proceedings contain the papers presented at the Fifteenth Annual Precise Time and Time Interval Applications and Planning Meeting which was held December 6-8, 1983 at the Naval Research Laboratory. The discussions following the presentations are also included. There were 261 registered attendees, of which 31 were from 13 foreign countries.

The objective of the meeting was to provide an opportunity for program planners to meet those who are engaged in research and development and to keep abreast of the state-of-the-art and latest technological developments. At the same time, it provided an opportunity for the engineers and scientists to meet program planners. This objective is clearly reflected by the title of the meeting.

This year, the program emphasized advances in Time and Frequency Services of the various national laboratories, the use of the NAVSTAR Global Positioning Service for time transfer, and the mathematics and statistical techniques used in PTTI. Specialized PTTI applications and systems for Time Transfer/Synchronization and PTTI System Components were also included in the program. For the second time in the history of the PTTI meetings, a well-attended classified session was held.

The Executive Committee wishes to express its appreciation of the excellent work of the Session Chairman and the Technical Program Committee. The quality of the program remains excellent as is evidenced by the increasing registration and continuing support of our sponsors. The key to the success of a meeting such as this depends on the unstinting support of many volunteers. We are fortunate to have such support from the sponsors. In particular, the efforts of Messrs. S. Clark Wardrip and James Murray must be recognized, as well as the hospitality of the Naval Research Laboratory.

CONTENTS

	<u>Page</u>
CALL TO SESSION Dr. William J. Klepczynski	1
WELCOMING ADDRESS Jim Murray	3
OPENING COMMENTS Dr. William J. Klepczynski	5
SESSION I ADVANCES IN TIME AND FREQUENCY SERVICES	
Timing Accuracy of LF and TV Synchronization Techniques Miao Yun-rui and Pan Xiao-pei	9✓
New Time and Frequency Services at the National Bureau of Standards S. R. Stein, G. Kamas and D. W. Allan	17✓
Recent Improvements in the Atomic Time Scales of the National Bureau of Standards D. W. Allan, D. J. Glaze, J. E. Gray, R. H. Jones, J. Levine, and S. R. Stein	29
Automation of Precise Time Reference Stations (PTRS) Paul J. Wheeler	41
U.S. Naval Observatory Collection and Utilization of Time Comparison Data. F. Neville Withington	53
International Time Comparison by a GPS Timing Receiver M.-K. Fujimoto, K. Fujiwara, and S. Aoki	71
SESSION II GPS TIME TRANSFER	
First Results of GPS Time Transfer to Australia John McK. Luck, John R. Woodger, James E. Wells, Peter N. Churchill and Philip A. Clements	87
Separating the Variances of Noise Components in the Global Positioning System David W. Allan and Marc Weiss	115
Enhancements to the TTS-502 Time Transfer System Dr. A. J. Van Dierendonck and Dr. Q. D. Hua	133

CONTENTS (continued)

	<u>Page</u>
A New Precision Time and Frequency Source for Stationary PTTI Applications	155
Javad M. Ashjaee, Roger J. Helkey and Ron C. Hyatt	
On-Orbit Frequency Stability Analysis of the GPS NAVSTAR's 3 and 4 Rubidium Clocks and NAVSTAR's 5 and 6 Cesium Clocks	171
Thomas B. McCaskill, James A. Buisson and Sarah B. Stebbins	
GPS Navigation Experiment Using High Precision GPS Timing Receivers . . .	211
J. Buisson, O. J. Oaks, M. Lister, S. C. Wardrip, S. Leschiutta, P. G. Galliano, F. Cordara, V. Pettiti, E. Detoma, P. Dachel, H. Warren, T. Stalder, F. Fedele and R. Azzarone	
Improved Master Clock Reference System at USNO	237
Gernot M. R. Winkler	
The Steering of GPS Time	249
H. F. Fliegel	
Test Results for Prototype GPS Rubidium Clocks	269
T. J. Lynch and W. J. Riley	

SESSION III TIME TRANSFER/SYNCHRONIZATION

International Time Transfer and Portable Clock Evaluation Using GPS Timing Receivers: Preliminary Results	283
S. C. Wardrip, J. Buisson, O. J. Oaks, M. Lister, E. Detoma, P. Dachel, T. Stalder, H. Warren, G. Winkler, G. Luther, S. Leschiutta, P. G. Galliano, F. Cordara, V. Pettiti, R. Azzarone and F. Fedele	
Spread Spectrum Time Transfer Experiment Via INTELSAT	331
Dr. P. Hartl, L. Veenstra, N. Gieschen, K.-M. Müssner, W. Schafer, C.-M. Wende, Dr. W. Klepczynski, H.-H. Nau and R. Stoiber	
Unattended TV Time Transfer Results	357
John A. Waak and John H. Spencer	
The Role of a Low Earth Orbiter in Intercontinental Time Synchronization Via GPS Satellites	371
Sien-Chong Wu and V. John Ondrasik	
Timing of Spacecraft Data	389
H. P. Dworak	

CONTENTS (continued)

	<u>Page</u>
UHF IRIG G Distribution System	413
M. Tope	
Timing System Design Considerations for a Mobile Astrolabe	423
Carl F. Lukac, Paul J. Wheeler, Richard E. Keating, and Randolph T. Clarke	
Precise Time Transfer Using MKIII VLBI Technology	443
K. J. Johnston, J. A. Buisson, M. J. Lister, O. J. Oaks, J. H. Spencer, W. B. Waltman, G. Elgered, G. Lundqvist, A. E. E. Rogers, T. A. Clark, C. Ma, A. C. Johnson, K. Kingham, W. J. Klepczynski, G. Luther, A. J. Kubic, and D. D. McCarthy	

SESSION IV MATHEMATICAL AND STATISTICAL TECHNIQUES AND THEIR APPLICATION TO PTTI

Clock Characterization Tutorial	459
David W. Allan	
Methods for Optimal Recursive Estimation of Non-Stationary Time Series, Applications to Atomic Time and Frequency Metrology	477
Z. Y. Weng, J. Rutman and J. Uebersfeld	
Applied Kalman Filtering: An Overview	503
R. Grover Brown	
Kalman Filtering with a Two-State Clock Model	519
Fran B. Varnum	
Kalman Filter Estimates of the NAVSTAR Satellite Clock Parameters	531
Paul S. Jorgensen	
The Measurement of Linear Frequency Drift in Oscillators	551
James A. Barnes	
A Plan for the Development of Inertial Reconstruction of Initial State Clock (IRIS)	583
Ernest G. Kimme, Ph.D.	

SESSION V PTTI COMPONENTS

High Performances from a New Design of Crystal Oscillator	621
G. Beauvy, G. Marotel and P. Renoult	
Design of SC Cut 10 MHz H.Q. Crystals with G. Sensitivity Better than $2 \cdot 10^{-10}/G$	635
A. Debaisieux, J. P. Aubry and J. Groslembert	

CONTENTS (continued)

	<u>Page</u>
Recent Results on the Performance of EFOS, NP and NX Hydrogen Masers V. Reinhardt, J. Ingold, T. Stalder, M. Saifi, P. Dachel and S. C. Wardrip	653
Physics Element Design Aspects for a Tactical Rubidium Frequency Standard. . Bruce Grover and Tae M. Kwon	677
Crystal Resonator/Oscillator Test Facility and Test Results. V. J. Rosati and R. L. Filler	693
Time Synchronization Experiments with Apple. C. L. Jain, K. Kumar, M. R. Sivaraman, B. S. Mathur, P. Banerjee, A. Sengupta, Mithlesh Saxana, A. K. Hanjura and A. K. Suri	707
The Superconducting Cavity Stabilized Ruby Maser Oscillator. G. J. Dick and D. M. Strayer	723
CLOSING REMARKS.	741

CALL TO SESSION

Dr. William J. Klepczynski
Program Chairman
United States Naval Observatory

DR. KLEPCZYNSKI: My name is Bill Klepczynski, and I am the program chairman for this meeting. Unfortunately, the general chairman of the meeting, Dr. Nicholas Yannoni, is ill and could not, therefore, make it for today. So, on his behalf, I would like to extend to you a hearty welcome for your attendance here at the Fifteenth Annual P.T.T.I. Meeting.

Authors of papers, Lauren Rueger, who is here, I'll ask him to stand up, he is to receive your paper sometime, during the three days of the meeting, for publication in the Proceedings of the Fifteenth Annual Precision Time and Time Interval Planning Conference.

For our welcoming address I would like to introduce Jim Murray of the Naval Research Laboratory.

WELCOMING ADDRESS

Jim Murray
Naval Research Laboratory

MR. MURRAY: I am sorry that our Commanding Officer, Captain McMorris, will not be able to be here for the welcoming address; but, on his behalf, I would like to extend to you a wish for a very successful meeting.

The laboratory is not new to this meeting. We have been associated with it for the past fifteen years, back to when it first started. During that time we have seen the number of sponsors increase by an order of magnitude; from one to ten, and we have seen the nanosecond replace the microsecond as the most talked about unit of time; and now we can even use picoseconds without a footnote. These are all signs of progress, and these are things that the timing community has done; but there's another sign of progress, and that's the growing number of users that describe their systems in terms of these units. For this, our meetings can take proper credit.

We are responsible for letting the potential users know what has been done, what is being done, and what is planned in timing. In this way, we have helped them to take advantage of the kinds of precise timing that can improve their systems.

P.T.T.I. meetings have been very successful in accomplishing their purposes, and I am sure this meeting will enjoy the same productivity as those in the past.

We have many foreign visitors here and we are very happy to have them. We are sorry for the inconvenience that our entry procedures have caused, but this is just part of our system that we cannot do without.

I welcome you here and I wish you success in your meeting.

OPENING COMMENTS

Dr. William J. Klepczynski
Technical Program Committee
United States Naval Observatory

DR. KLEPCZYNSKI: I would like to talk about the program very briefly. As Jim mentioned, today microsecond timing is available throughout most of the world; and in some instances, we have nanosecond timing. This has really taken place in the last fifteen or sixteen years. I think the first Hewlett-Packard cesium box came out about 1967 or '68, and ever since that time the timing community and users of precise time have made quantum leaps in their systems; and the programs reflect some of these advances.

The first session we have is devoted to advances in the services provided by the various national laboratories.

We have another session on G.P.S. time transfer; one of the most up-to-date systems, which will assure nanosecond timing throughout the world.

One session is devoted to the mathematics of precision time and frequency. Since we have not dealt with that for a long time, we thought some interesting tutorials would be worthwhile for the people who attend the meetings.

There is one classified session which will not be held in this auditorium; it will be held in a separate building and is restricted to cleared U.S. citizens. So please take this into consideration.

If you have a question would you identify yourself, because the sessions are being recorded for the proceedings of the conference, and we can then get your name and affiliation as well as your words.

With that, I would like to introduce the chairman of the first session, Dr. Derek Morris, National Research Council of Canada.



SESSION I

ADVANCES IN TIME AND FREQUENCY SERVICES

Dr. Derek Morris, Chairman
National Research Council
Canada

CALL TO SESSION I

DR. DEREK MORRIS: Good morning. This session is called Advances in Time and Frequency Services, and I understand at the moment that five of the six papers will be given. If the authors of the last paper are here, I would appreciate it if they would identify themselves to me; if not, we will start right away, and I would ask the speakers, please, to keep to twenty minutes for their presentations. If it's slightly less than that, we will have time for one or two questions; but we have a deadline to reach lunch by 11:50, so we will have to keep the session moving.